515.06. BASIS OF PAYMENT.

Accepted quantities of penetrating water repellent treatment of concrete surfaces other than bridge decks and approach slabs, accepted according to Subsection 515.04(d)1, will be paid for at the contract unit price for:

(A) WATER REPELLENT (VISUALLY INSPECTED)....SQUARE YARD (SQUARE METER)

Accepted quantities of penetrating water repellent treatment of bridge decks and approach slabs, accepted for payment according to Subsection 515.04(d)2, will be paid for at the adjusted contract unit price for:

(B) WATER REPELLENT (PERFORMANCE TESTED).SQUARE YARD (SQUARE METER)

Payment for the above pay items shall be full compensation for furnishing all materials, equipment, labor and incidentals to complete the work as specified.

SECTION 516
DRILLED SHAFT FOUNDATIONS

516.01. DESCRIPTION.

This work consists of constructing drilled shafts including the furnishing and placing of reinforcing steel and concrete, all in accordance with the contract documents.

516.02. MATERIALS.

(a) **General.** Materials shall conform to the requirements specified herein and the following sections:

Structural Concrete	509
Reinforcing Steel for Structures	511

(b) **Concrete.** Furnish Class AA concrete modified as follows. Limit the maximum nominal aggregate size to 3/4 inch (19mm) . Increase minimum cement content 10% for concrete placed under water or slurry.

Adjust approved admixtures for site conditions to ensure that the concrete has at least 6 inches (150 mm) of slump at the start of placement and at least 4 inches (100mm) of slump at the completion of placement and casing/reinforcement alignment. Maintain the concrete temperature under 85°F (30°C) during placement.

(c) **Casings.** For all exterior casings, use smooth, clean, watertight, steel casings of ample strength to withstand handling and driving stresses, and the concrete and surrounding earth pressures. The dimensions of a permanent casing is subject to American Pipe Institute tolerances applicable to regular steel pipe. If only a single casing is used in a shaft, the casing is considered an exterior casing.

For permanent exterior casings, use steel conforming to AASHTO M270 Grade 36 (ASTM A709M Grade250) unless otherwise specified. Perform welding of permanent exterior casings by Section 506. Permanent exterior casing diameters shown on the plans are outside diameters.

For permanent interior casings, use round corrugated galvanized steel pipe with 3 inch (75 mm) x 1 inch (25 mm) corrugations meeting AASHTO M36, and of sufficient gauge to maintain a round shape and withstand the pressure of the concrete.

516.04. CONSTRUCTION METHODS.

(a) **Contractor Qualifications.** Use personnel with appropriate experience for the construction of drilled shafts.

Submit an installation plan for informational purposes before constructing drilled shafts. Include the following information in the plan for all drilled shafts.

- Details of reinforcement placement including support and centering methods.
- Details of concrete placement including proposed operational procedures for tremie and pumping methods.
- Details of the concrete mix design including results of concrete trial mix and slump loss tests.

Include the following additional information in the plan for slurry displacement drilled shafts.

- List of proposed equipment to be used including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies, concrete pumps, casings, etc. (Analyze the capacity of the equipment to drill the size, depth, and hardness of the planned excavations.)
- Details of overall construction operation sequence and the sequence of shaft construction in bents or groups.
- Details of shaft excavation methods and procedures for maintaining correct horizontal and vertical alignment of the excavation.
- Details of excavated materials use or disposal.
- Details of the methods to mix, circulate, desand, dispose of the slurry.
- Details of methods to clean the shaft excavation.
- Personnel resumes of project experiences and appropriate documentation including names, addresses, and telephone numbers of organizations or associations that verify the information.

Revise and resubmit if the installation plan does not provide satisfactory results. Submit any request for changing the top of shaft elevations, as needed, with the installation plan.

(b) **Trial Drilled Shafts.** If trial drilled shafts are required by the contract, demonstrate that the methods and equipment described by proposed installation plan are capable of constructing the required drilled shafts by constructing a trial drilled shaft adjacent to the permanent shafts at an approved location, before constructing the permanent drilled shafts.

Construct the trial shaft to the same size and to the tip elevation of the deepest shaft shown on the plans. Leave completed excavation open for a minimum of four hours before concreting to monitor excavation stability and groundwater seepage. Clean the excavation and place the approved mix design concrete, filling the hole completely. Remove the concrete down to 2 feet (0.6 m) below the finished grade. Reinforcing steel is not required in trial drilled shafts.

If the trial drilled shaft is determined to be unsatisfactory, modify the installation plan appropriately, resubmit the new installation plan, and drill a new trial drilled shaft.

Once approval is given to construct the permanent drilled shafts, no changes are permitted in the installation plan without resubmission.

(c) **Drilled Shafts.**

1. *Hole Excavation.* Excavate holes according to the installation plan.

Before drilling, excavate for structure footings supported on drilled shafts and construct embankments and fills.

Position the drilled shaft within 3 inches (75 mm) of the required position in a horizontal plane at the top of the shaft elevation. Do not allow the alignment of a vertical shaft to vary from the required alignment by more than 1% of shaft depth. Do not allow the alignment of a battered shaft to vary from the required battered alignment by more than 2% of shaft depth.

Use excavation equipment and methods that provide a bottom to the completed shaft that is normal to the axis of the shaft within 5% of the shaft diameter. Measurement of this shaft bottom tolerance will be left to the discretion of the Engineer. Use excavation equipment that provides a shaft diameter not more than one inch smaller than the required diameter.

Excavate to the plan elevation, extending the excavation below the plan elevation only when it is determined that the load bearing material encountered during excavation does not satisfy plan requirements. Take soil samples or rock cores as shown on the plans or directed by the Engineer to determine the character of the material directly below the shaft excavation. Immediately notify the Engineer of any significant deviation from the plans in subsurface conditions that may result in a shaft depth change.

Check dimensions and alignment of each shaft excavation in the presence of the Engineer before concrete placement. Final shaft depth shall be measured after final cleaning.

When it is determined that the hole sidewall has softened due to excavation methods, swelled due to delays in concreting, or degraded as a result of slurry cake buildup, overream the sidewall a minimum of $^1/_2$ inch (12mm) and maximum of 3 inches (75 mm) to sound material.

Immediately before concrete placement, clean the hole so not more than 50% of the bottom of each hole has more than $^1/_2$ inch (12 mm) of sediment and the maximum depth of sediment or debris at any place on the bottom of the hole does not exceed $1^1/_2$ inches (38 mm) For dry holes, reduce the depth of water to 6 inches (150 mm) or less before placing concrete.

Use one or more of the following methods for excavation. Do not use methods prohibited by the plans or special provisions.

1.1 *Dry Method.* Use the dry construction method at sites where the groundwater level and soil conditions are suitable to permit construction of the shaft in a relatively dry

excavation and where the sides and bottom of the shaft may be visually inspected before placing concrete. The dry method consists of drilling the shaft, removing accumulated water, removing loose material from the excavation, placing the reinforcing cage, and concreting the shaft in a relatively dry condition. When caving, sloughing, or swelling conditions exist or when groundwater seepage exceeds the described limits, discontinue and use an approved alternative method.

1.2 *Wet Method.* Use the wet construction method or a casing construction method for shafts that do not meet the above requirements for dry construction method. The wet method consists of using water or slurry to maintain stability of the hole perimeter while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft. The wet method may involve the following work.

- Desanding and cleaning the slurry.
- Final cleaning of the excavation using a bailing bucket, air lift, submersible pump, or other approved devices.
- Placing the shaft concrete with a tremie or concrete pump beginning at the shaft bottom.
- Providing temporary surface casings to aid shaft alignment and positioning.
- Providing temporary surface casings to prevent sloughing of the top of the shaft excavation unless it can be satisfactorily demonstrated that the surface casing is not required.

Refer to Subsection 516.04(c)2 for slurry requirements.

1.3 *Casing Methods.*

1.3.1 *General.* For all casing methods, do not case to the bottom of the shaft. Discontinue the casing at the top of the founding stratum as shown on the Plans. Continue excavating below the casing using either the dry or wet method. To provide design frictional load capacity, excavate into the founding stratum the length shown on the Plans or to Plan depth, whichever is deepest. Refer to Subsection 516.04(c)3, *Exterior Casings*, for casing installation requirements.

1.3.2 *Temporary Casing Method.* Use the temporary casing construction method at sites where the dry or wet methods are inappropriate. This method consists of advancing the excavation through caving material into a nearly impervious formation by the wet method, setting a casing, completing excavation, placing the reinforcing cage, and concreting the shaft while removing the casing. As an alternate process for excavating through the caving material and setting the casing, drive or drill the casing into the nearly impervious formation, then proceed with excavation.

1.3.3 *Permanent Casing Method.* Use the permanent casing construction method when required by plans or where drilled shafts are located in open water areas. This method consists of advancing the excavation through caving material by driving or drilling a permanent casing to a prescribed depth or a nearly impervious formation whichever is deepest, excavating to the final depth, placing the

reinforcing cage, and concreting the shaft.

If during casing installation full penetration cannot be attained, excavate within the embedded portion of the casing. Drill a pilot hole if necessary. Casing shall be continuous from the top of the shaft to the elevation shown on the plans.

Where drilled shafts are located in open water areas, extend casings from above the water elevation into the ground to protect the shaft concrete from the water action during placement and curing of the concrete.

1.3.4 *Double Casing Method.* Use the double casing construction method when specified in the contract documents or as an alternate for the temporary casing method when groundwater or unstable soil conditions are severe. This method is similar to the temporary casing method except that the temporary exterior casing is larger than the specified shaft diameter and a permanent interior casing (corrugated galvanized steel pipe) is set into the top of the founding stratum after the excavation is complete.

Supply the interior casing with a permanent inner diameter equal to the plan shaft diameter, and use a temporary exterior casing having an inner diameter at least 6 inches (150mm) larger than the interior casing. After the exterior casing is in place, complete the excavation to the plan shaft diameter and set the interior casing into the top of the founding stratum, bracing the interior casing at the top. Remove the temporary casing after filling interior casing with concrete, adding concrete as needed to maintain top of shaft elevation during removal. Do not adjust the interior casing position after the concrete has taken initial set.

1.4 *Obstructions.* When excavation through unexpected manmade materials cannot be advanced, the removal of the manmade materials is considered an obstruction. Removal of naturally-occurring material, regardless of difficulty or removal method, is not considered an obstruction. **Removal of tools lost in the excavation by the Contractor is not considered an obstruction.**

Remove obstructions when encountered. Inform the Engineer, in advance, of the proposed method for obstruction removal. If additional compensation for obstruction removal is sought, include a cost estimate for excess costs under Subsection 104.03. Do not use blasting methods unless approved by the Engineer.

2. *Slurry.* Premix the slurry material with clean fresh water according to the slurry manufacturer to allow for hydration before introduction into the shaft excavation. Use slurry tanks of adequate capacity for slurry circulation, storage, and treatment. Do not use excavated slurry pits. Use either mineral (bentonite or attapulgite) or polymer slurry.

Provide desanding equipment to limit slurry sand content at any point in the bore hole to less than 4 percent by volume for mineral slurry and less than 1 percent by volume for polymer slurry. Desanding is not required for setting temporary casings.

During drilling, maintain a slurry surface in the shaft at least 4 feet (1.2 m) above the highest expected water table elevation and at a level sufficient to prevent caving of the hole.

When there is a sudden significant loss of slurry from the hole, stop drilling and take corrective action to prevent slurry loss. Prevent the slurry from "setting up" in the shaft. If at any time the slurry construction method fails to produce the desired results, stop and use an approved alternative method.

When the excavation is to the required elevation and clean, allow at least 30 minutes for polymer slurry to stand undisturbed and then clean the base of the excavation with either a submersible pump or air lift.

Maintain the density, viscosity, and pH of the slurry during shaft excavation within the acceptable ranges shown in Table 516-1 for mineral slurry and Table 516-2 for polymer slurry.

Table 516-1
Acceptable Range of Values for Mineral Slurry

Property	At the time of Slurry Introduction	In Hole at Time of Concreting	Method
Density (lb/ft^3)	64.3 - 69.1	64.3 - 75.0	Density Balance
Viscosity (sec/qt)	28 - 45	28 - 45	Marsh Cone
pH	8 - 11	8 - 11	pH paper or meter

Table 516-2
Acceptable Range of Values for Polymer Slurry

Property	At the time of Slurry Introduction	In Hole at Time of Concreting	Method
Density (lb/ft^3)	62.4 - 63.0	62.4 - 63.5	Density Balance
Viscosity (sec/qt)	30 - 40	30 - 40	Marsh Cone
pH	9 - 11	9 - 11	pH paper or meter

Notes for Tables 516-1 and 516-2: Density values shown are for fresh water. Increase density values 2.0 lb/ft^3 32 kg/m^3) for salt water. Perform tests when slurry temperature is above 40°F.

Table 516-1 (Metric)
Acceptable Range of Values for Mineral Slurry

Property	At the time of Slurry Introduction	In Hole at Time of Concreting	Method
Density (kg/m^3)	1030-1107	1030-1200	Density Balance
Viscosity (sec/l)	30-48	30-48	Marsh Cone
pH	8-11	8-11	pH paper or meter

Table 516-2 (Metric)
Acceptable Range of Values for Polymer Slurry

Property	At the time of Slurry Introduction	In Hole at Time of Introduction	Method
Density (kg/m^3)	1000-1010	1000-1017	Density Balance
Viscosity (sec/l)	32-42	32-42	Marsh Cone
pH	9-11	9 - 11	pH paper or meter

Notes for Tables 516-1 and 516-2: Density values shown are for fresh water. Increase density values 32 kg/m^3 for salt water. Perform tests when slurry temperature is above 4°C.

Take slurry samples using an approved sampling tool. Extract slurry samples from the base of the shaft and 10 feet (3 m) above the base of the shaft. Perform four sets of tests during the first eight hours of slurry use. When the results are acceptable and consistent, the testing frequency may be decreased to one test set for every four hours of slurry use.

When a slurry sample is unacceptable, make necessary corrections to bring the slurry within specifications. Do not place concrete until the results of the resampling and retesting indicate acceptable values.

Furnish reports of all tests, signed by an authorized representative, after completion of each drilled shaft. Dispose of slurry at approved locations.

3. *Exterior Casings.* Install all casings to produce a positive seal that prevents piping of water or other material into or from the hole. If it becomes necessary to remove a casing and substitute a longer or larger diameter casing through caving soils, stabilize the excavation with slurry or backfill before the new casing is installed. Other approved methods may be used to control the stability of the excavation and protect the integrity of the foundation soils.

   All subsurface exterior casings are to be considered temporary unless designated in the contract as permanent casing. Remove temporary casing before completing placement of concrete in any cased drilled shaft. During casing removal from the hole, maintain a level of fresh concrete in the casing that is a minimum of 5 feet (1.5 m) above the surrounding level of water or slurry. Exercise care during casing removal to maintain an adequate level of concrete within the casing so fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete.

   Temporary casings that have become bound or fouled during shaft construction and cannot be practically removed are considered a defect in the drilled shaft.

   Extend casings above the ground surface to keep the excavation clean through concrete placement. When a casing is designated as permanent, cut the casing off at the required elevation and leave in place after concrete placement.

4. *Reinforcing Steel Cages for Drilled Shafts.*

   4.1 *General.* Place the reinforcing steel cage as a unit immediately after the shaft excavation is inspected and accepted and before concrete placement. Securely wire together contact

reinforcing steel lap splices. If the concrete is not placed immediately after the cage is installed, the cage may have to be removed before placing the concrete to verify the integrity of the excavated area and to ensure loose material is removed from the bottom of the hole.

Tie and support the reinforcing steel so it remains within the required tolerances. Securely tie concrete spacers or other approved spacing devices at fifth points around the cage perimeter and space at intervals not to exceed 10 feet (3 m) along the length of the cage. Use spacers of approved material equal in quality and durability to the shaft concrete.

During concrete placement, provide positive support from the top for the reinforcing steel cage. Support the cage concentrically to prevent racking and distortion of the cage. Maintain the top of the reinforcing steel cage no more than 6 inches (150 mm) above and no more than 3 inches (75 mm) below the required position. If the reinforcing steel cage is not maintained within tolerances, make acceptable corrections and do not construct additional shafts until the method of reinforcing steel cage support has been approved.

If it is determined in the field that the shaft must be longer than planned, provide reinforcing steel for the extended length.

4.2 *Access Tubes for Crosshole Sonic Logging (CSL).* When CSL access tubes are specified in the contract documents, i.e., shown in the bid schedule, provide CSL testing access tubes for all drilled shafts including trial shafts.

Use access tubes made of schedule 40 steel pipe and having an inside diameter of 2.0 inches (50 mm) . The tubes, including pipe joints, shall have a round, regular internal diameter free of defects or obstructions to permit the free, unobstructed passage of a 1.3 inches (33 mm) diameter source and receiver probes. The tubes and joints shall be watertight and free from corrosion with clean internal and external surfaces to ensure passage of the probes and a good bond between the concrete and the tubes.

Install each access tube the full depth of each shaft to permit access of CSL testing equipment. Using the planned shaft diameter, determine and install the number of access tubes in each drilled shaft as specified in Table 516-3, unless otherwise specified in the contract documents.

Table 516-3
Minimum Number of Access Tubes per Drilled Shaft

Planned Shaft Diameter, ft.(m)	Minimum Number of Access Tubes
$D \leq 3.0$ (0.9)	3
3.0 (0.9) $< D \leq 4.0$ (1.2)	4
4.0 (1.2) $< D \leq 5.0$ (1.5)	5
5.0 (1.5) $< D \leq 6.0$ (1.8)	6
6.0 (1.8) $< D \leq 8.0$ (2.4)	7
8.0 (2.4) $< D \leq 10.0$ (3.0)	8
10.0 (3.0) $< D \leq 12.0$ (3.7)	9

Fit each tube with a watertight shoe on the bottom and a removable cap on the top. Securely attach the tubes to the interior of the reinforcement cage in a regular, symmetric pattern such that each tube is equally spaced from the others around the perimeter of the cage. Install the tubes as near to parallel and vertical as possible. Start the tubes at the shaft bottom and end at least 3 feet (0.9 m) above the shaft top. If the shaft top is subsurface, extend the tubes at least 3 feet (0.9 m) above the ground and/or water surface.

Take care during reinforcement installation operations in the drilled shaft hole so as not to damage the tubes. Before placement of concrete, fill the access tubes with clean water and cap the tube tops to keep out debris. After concrete placement, exercise care when removing caps to avoid applying excess torque, hammering, or other stresses that could break the bond between the access tubes and the concrete.

5. *Concrete for Drilled Shafts.* Place concrete immediately, except as otherwise specified, after all excavation is complete and the reinforcing steel cage is in place. Complete concreting in a shaft, including the removal of temporary casing, within two hours of starting concrete placement. Do not retemper concrete that has developed initial set.

Before placement in a wet hole, allow water in the hole to seek its natural hydraulic head.

Place concrete in one continuous operation from bottom to top of the shaft using either a tremie or concrete pump. Continue placing concrete after the shaft excavation is full and until acceptance quality concrete is evident at the top of the shaft. Before initial concrete set, consolidate the top 10 feet (3.0 m) of the shaft concrete using acceptable vibratory equipment. Finish the top of the shaft within 1 inch (25 mm) higher to 3 inches (75 mm) lower than the required elevation. For wet holes, do not consolidate until all water above the concrete surface has been removed.

Place the discharge end of either a tremie or concrete pump at the shaft base elevation. Keep the discharge end immersed at least 5 feet (1.5 m) below the surface of the fluid concrete. Maintain a positive head of concrete in the tremie or pump during concrete placement. If anytime during the concrete placement, the discharge end is removed from the fluid concrete column and discharges concrete above the rising concrete surface into displaced water, remove the reinforcing cage and concrete, complete any necessary sidewall removal as directed, and reconstruct the shaft.

When the top of the shaft is above ground, use a removable form or other approved means to form the shaft from the top to a minimum of 2 feet (0.6 m) below finished ground. When the top of the shaft is below ground, use a temporary oversize surface casing to control caving of soil, etcetera, into the freshly placed concrete.

Concrete will be sampled for acceptance at the point of discharge into the tremie or concrete pump hopper. Cure exposed concrete surfaces by Section 509.

5.1 *Tremies.* Use watertight tremies for concrete placement in either wet or dry holes. A tremie consists of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base. Make the tremie so that the bottom can be sealed and charged with concrete in the dry, and then opened when in place at the bottom of the shaft. Do not

use tremies that contain aluminum parts that will contact the concrete. Make the tremie capable of being rapidly lowered to retard or stop the flow of concrete.

Make the tremie inside diameter at least 10 inches (250 mm) and not more than 14 inches (350 mm) . Make the inside and outside surfaces of the tremie clean and smooth. Make the wall thick enough to prevent crimping or sharp bends. Fit the top with a hopper. Construct the discharge end of the tremie to permit free radial flow of the concrete during placement.

5.2 *Concrete Pumps.* Use pumped concrete placement in either wet or dry holes. Use 4-inch (100 mm) minimum diameter discharge tubes with watertight joints. Place the discharge tube at the shaft base elevation.

For wet holes, use pumps with a device at the end of the discharge tube to seal out water while the tube is first being filled with concrete. If a plug is used, remove it from the hole or use a plug made from approved material that will prevent a defect in the shaft if not removed.

6. *Nondestructive Testing of Drilled Shafts.*

6.1 *General.* Provide Crosshole Sonic Logging (CSL) testing to check the integrity of concrete drilled shafts when CSL testing is required by the contract documents, i.e., shown in the bid schedule. If CSL access tubes are required by the contract document but CSL testing was not required by the contract documents and, in the opinion of the Engineer, a construction problem was observed during shaft construction, the Department will conduct CSL testing. If access tubes were not specified or installed, the Engineer may require full depth coring to determine the soundness of a questionable drilled shaft (see 514.04(c)6.7).

6.2 *NDT Consultant.* When CSL testing is required by the contract documents, provide a Nondestructive Testing (NDT) consultant experienced in CSL testing. Submit resumes of the consulting personnel for approval before testing. Perform all CSL testing and analyses under the supervision of an Oklahoma registered Professional Engineer. The consultant shall have a minimum of one year experience in field testing and analyzing CSL testing.

6.3 *Testing Schedule.* Wait at least 24 hours after the placement of all concrete in a shaft before CSL testing. After placement of concrete, finish CSL testing within 30 calendar days for steel access tubes.

6.4 *CSL Test Equipment.* Use CSL test equipment capable of performing the following functions:

- Displaying individual CSL records, recording CSL data, and analyzing receiver responses.
- Printing of CSL logs.
- Testing in 2 inches (50 mm) I.D. access tubes.
- Generating an ultrasonic voltage pulse to excite the source with a synchronized triggering system to start the recording system.

- Measuring and recording the depths of CSL probes at the time signals are recorded.
- Filtering/amplifying signals.

6.5 *CSL Logging Procedures.* Test all perimeter tube pairs and major diagonal tube pairs. If a possible defect is indicated, conduct CSL testing between additional pairs of tubes as determined by the NDT consultant.

Perform CSL tests with the source and receiver probes in the same horizontal plane unless test results indicate potential defects. Angled tests consisting of the source and receiver vertically offset in the access tubes may be made to further evaluate a questionable zone. Make CSL measurements at depth intervals of 2 inches (50mm) . Pull the probes, starting from the bottom of the tubes, over a depth-measuring device. Remove any slack from the cables before pulling to provide accurate depth measurements. Report to the Engineer any indicated defects and conduct further tests as required to evaluate the extent of such defects.

6.6 *CSL Testing Results*. Provide a preliminary report to the Engineer within 72 hours of CSL testing. Furnish, within 10 working days of testing, two copies of the final CSL testing report sealed by the Professional Engineer supervising the testing. Include in the final report the CSL logs with analyses of the initial pulse arrival time versus depth and pulse energy/amplitude versus depth. Present a CSL log for each tube pair tested with any defect zones indicated on the logs and discussed in the test report as appropriate. Include in the report a summary of the CSL test results which covers drilled shaft identification, test date, shaft age at time of CSL testing (days from concrete placement to CSL testing), drilled shaft diameter, number of CSL tubes tested, test length, average compression velocity, and a description of defects detected. In each defect description, include the CSL tube number, depth below top of concrete, percent concrete wave speed reduction, and recommended concrete condition rating. The Engineer will evaluate the CSL test results and determine whether the drilled shaft construction is acceptable.

6.7 *Core Drilling of Drilled Shaft Concrete.* If a drilled shaft is believed to be unacceptable, the Engineer may require continuous coring of the shaft using an "NW" size core barrel as specified in ASTM D 2113. The number, depth, and location of cores will be determined by the Engineer. Submit the methods and equipment used to core the drilled shaft and grout the cored hole to the Engineer for approval before coring.

Place the cores in a crate and properly mark showing the shaft depth at each interval of core recovery. Submit the cores and an accurate log for each core recovered. Do not proceed with construction above the drilled shaft in question until the quality of the concrete in the shaft, as represented by the core samples, is determined to be acceptable and notification to continue construction is given by the Engineer. If the quality of the concrete in a drilled shaft is determined to be unacceptable, then the drilled shaft will be considered defective.

6.8 *Abandoning CSL Access Tubes.* After completing CSL testing and the Engineer has approved continuing construction above the shafts, dewater and Portland cement grout the access tubes in the drilled shafts. Submit the grout mix design and grouting method for approval.

7. *Defective Shafts.* Correct defective shafts using approved methods. Submit for approval a plan for corrective work. Corrective action may consist of, but not limited to, the following.
   - Removing the shaft concrete and extending the shaft deeper to compensate for loss of frictional capacity in the cased zone when temporary casing cannot be removed.
   - Providing straddle shafts to compensate for capacity loss.
   - Providing a replacement shaft.

516.05. METHOD OF MEASUREMENT.

Accepted lengths of *drilled shafts* and *trial drilled shafts* shall be measured by the linear foot (meter) from the shaft base elevation to the top of shaft elevation. Measurements shall be based upon the planned elevations or the elevations approved by the Engineer. Additional work for the correction of defective shafts shall not be measured for payment. Miscellaneous items, such as, soil samples or rock cores specified in the contract documents, rebar splices, permanent casings, tools and equipment lost, overreamed excavation, surface excavation or backfill needed for construction, and concrete placed outside the neat lines of the shaft shall not be measured for payment.

Accepted lengths of *Crosshole Sonic Logging (CSL) access tubes* shall be measured by the linear foot (meter) of tubing when shown in the bid schedule. Tube lengths measured for payment shall not exceed the actual length of tubing in place or the limits of tubing required by these specifications. CSL testing shall be measured for payment per drilled shaft tested when shown in the bid schedule. Additional testing (CSL and coring) to determine extent of defects shall not be measured for payment.

Approved obstructions shall be measured by lump sum. No reduction shall be made in drilled shaft measurements due to obstructions.

516.06. BASIS OF PAYMENT.

Accepted quantities of drilled shafts, measured as provided above, will be paid for at the contract price per unit of measurement for the pay items listed below that are shown in the bid schedule. Payment will be made under:

(A) DRILLED SHAFTS ..... LINEAR FOOT (METER)
(B) TRIAL DRILLED SHAFTS ..... LINEAR FOOT (METER)
(C) CROSSHOLE SONIC LOGGING ..... EACH
(D) CSL ACCESS TUBES ..... LINEAR FOOT (METER)

which will be full compensation for all material, labor, equipment and incidentals necessary to complete the work described in this section. Approved obstructions will be paid for by Supplemental Agreement. Either soil samples or rock cores not specified by the Plans will be paid for by Supplemental Agreement. Nondestructive testing by the Department, revealing structural defects requiring corrective action, shall be paid for by the Contractor. Contractor coring, required by the Engineer and not revealing structural defects, shall be paid for by Supplemental Agreement. Contractor coring, required by the Engineer and revealing structural defects, shall be paid for by the Contractor.